MORTALITY AND POPULATION DYNAMICS OF *BEMISIA TABACI* WITHIN A MULTI-CROP SYSTEM

S.E. Naranjo[1], L. Cañas[2], & P.C. Ellsworth[3]

[1]USDA-ARS, Arid-Land Agricultural Research Center, 21881 N Cardon Lane, Maricopa, Arizona, U.S.A., steve.naranjo@ars.usda.gov; [2]Department of Entomology, Ohio State University, OARDC, 1680 Madison Avenue, Wooster, Ohio, U.S.A., canas.4@osu.edu; [3]Department of Entomology, University of Arizona, Maricopa Agricultural Center, 37860 W. Smith-Enke Road Maricopa, Arizona, U.S.A., peterell@cals.arizona.edu

ABSTRACT.

The population dynamics of mobile polyphagous pests is governed by a complex set of interacting factors that involve multiple host-plants, seasonality, movement and demography. *Bemisia tabaci* is a multivoltine insect with no diapause that maintains population continuity by moving from one host to another over the year. To better understand the mechanisms governing population development of this insect within the landscape, whitefly "ecosystems" were established in three geographically and climatically distinct areas in Arizona. These systems consisted of a sequence of six representative hosts (winter broccoli, spring and fall cantaloupes, summer cotton, perennial alfalfa, various annual weeds, and the perennial ornamental, lantana). Source and rates of natural mortality were quantified, *in situ*, on each host plant by life tables. The quantitative contribution of each mortality factor varied among hosts and time of the year, but was relatively consistent among geographic sites. Predation (sucking insects) and dislodgement from the plant surface (largely chewing predation) were consistently the largest sources of mortality. Median generational mortality was generally > 90% except on spring-planted cantaloupe where median mortality was <70%. Low mortality during the spring on cantaloupe appears to act as a biotic release leading to outbreak populations during summer months. Overall, an understanding of the year round spatio-temporal dynamics of this pest and its associated natural enemies will greatly aid the development of better pest management strategies in all affected crops.

INTRODUCTION.

The concept that pest populations can be more efficiently managed at the landscape level has been viewed as a central, but little used, component of IPM for many decades (Rabb 1978; Kogan 1998). Such an approach is even more crucial to mobile, polyphagous pests which can readily exploit a wide range of both crop and non-crop hosts over time (Kennedy & Storer 2000). Implicit in this community perspective of pest management is the need for an understanding of and an ability to exploit natural enemies of the pest on an equivalent spatial scale (Landis & Menalled 1998; Schmidt *et al.* 2004).

The sweetpotato whitefly, *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) is a pest of worldwide significance (Naranjo & Ellsworth 2001). The pest causes direct feeding damage, vectors over 110 plant viruses, induced plant disorders, and reduces yield quality through honeydew excretion. The pest potential of *B. tabaci* is exacerbated by its polyphagy, high reproductive rate, dispersal ability and lack of a quiescent stage that enables year-round population development on a sequence of host plants in the landscape (Fig. 1).

The development of sustainable, ecologically-based management strategies for *B. tabaci* will depend on a mechanistic understanding of the complex, and interacting temporally and spatially-varying factors governing pest population development in a mosaic of hosts throughout the year. Various mortality agents including predation, parasitism, dislodgement from the plant surface, insecticides and physiological factors affect the survival of *B. tabaci* (Naranjo & Ellsworth 2005). An understanding of the timing, spatial distribution and magnitude of these mortality factors is central to their exploitation in pest management systems. Field-based life table studies were conducted over a three year period to quantify natural mortality and describe population change in multi-host systems in three regions of Arizona. Our goal was to compare and contrast the natural mortality factors affecting populations of *B. tabaci* at different times of the year to provide a mechanistic understanding of the pest's population dynamics and potential biological control in a landscape context.

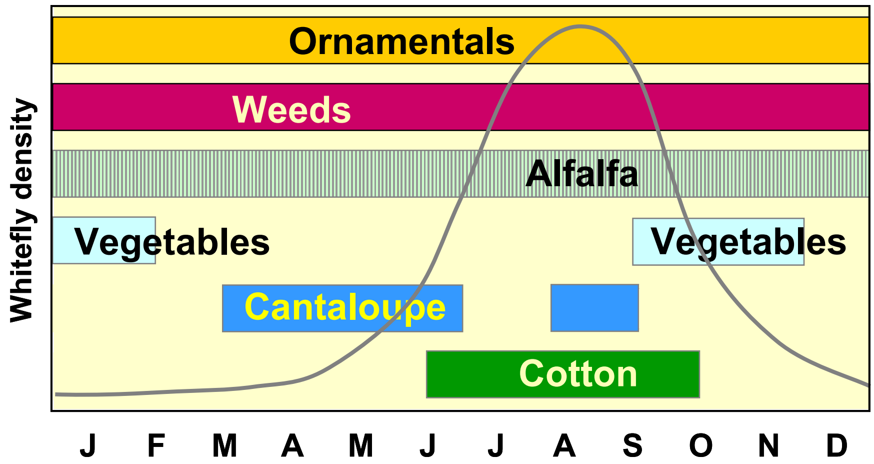

Fig. 1. A typical seasonal cycle of *B. tabaci* in a multi-host system in Arizona. Populations persist at low levels during winter months and may reach outbreak levels in summer in crops such as cotton.

<u>MATERIALS AND METHODS.</u>

Study sites were established in three geographically and climatically distinct areas in Arizona. In each area we established whitefly "ecosystems" consisting of a sequence of six representative hosts including winter broccoli, spring and fall cantaloupes, summer cotton, perennial alfalfa, various annual weeds, and the perennial ornamental, *Lantana*. No insecticides were used.

An *in situ* life table technique (Naranjo & Ellsworth 2005) was used to identify and quantify sources and levels of natural mortality affecting immature stages (eggs and nymphs) of *B. tabaci* on each host plant. Life table studies were conducted multiple times on each host plant throughout 3 years of study. Mortality was categorized as due to inviability (eggs only), dislodgement from the plant surface, parasitism, predation, desiccation, or other unknown factors (Fig. 2). Because multiple mortality factors act contemporaneously, stage-specific, marginal rates of mortality were estimated for each factor based on apparent mortalities (Royama 1981; Elkinton *et al*. 1992; see Naranjo & Ellsworth 2005 for equations).

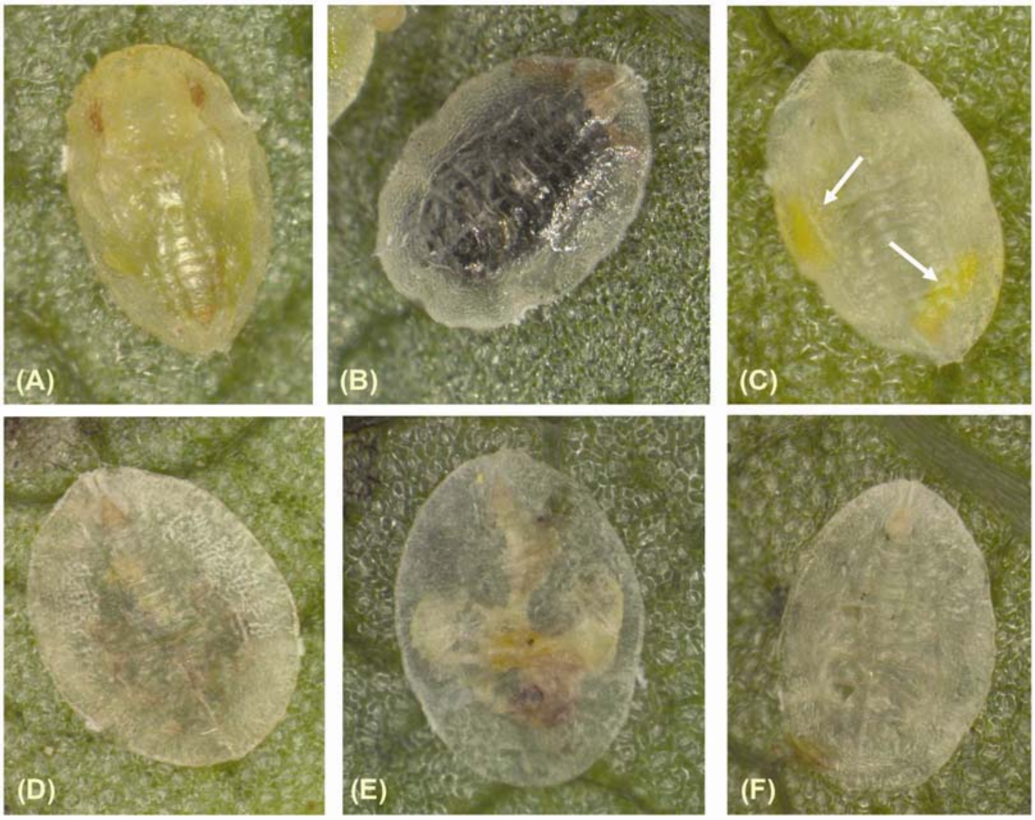

Fig. 2. Examples of natural-enemy induced mortality of *B. tabaci*; (A) *Eretmocerus* sp. parasitism, (B) *Encarsia* sp. parasitism, (C) early stage parasitism (displacement of mycetomes denoted by arrows), (D-F) predation by sucking predators.

RESULTS.

Generally, the same mortality factors were observed on all host plants; however, the relative contribution of each individual factor varied among host plants and the time of the year that they were grown (Fig. 3). Predation (primarily by sucking predators) and dislodgement (due to weather and chewing predators) were consistently the largest sources of mortality on all host plants except broccoli. Parasitism by aphelinids (*Eretmocerus* spp. and *Encarsia* spp.) was moderately high in alfalfa, lantana, fall cantaloupe and cotton (at the Maricopa site) and low on all other hosts. Egg inviability was consistently low throughout, but desiccation was highly variable across and within host plants depending on region. Desiccation was primarily associated with freezing temperatures that affected the insect or the host leaf it inhabited.

Generational mortality was variable but median mortality was > 91% in all hosts but spring-planted cantaloupes at the Maricopa and Yuma sites and fall cantaloupe at the Marana site where median mortality was <72%. Partitioned by season, predation and dislodgement were consistently the largest sources of mortality (not shown). Parasitism was moderately high during the summer and fall, while desiccation was greatest during the fall and winter.

Mortality was not evenly distributed over the egg and four nymphal stages and in general, mortality was greatest during the 4th stadium, followed by mortality during the egg stage. The one exception was winter-grown broccoli in which considerable mortality also occurred during the 1st and 2nd nymphal stadia.

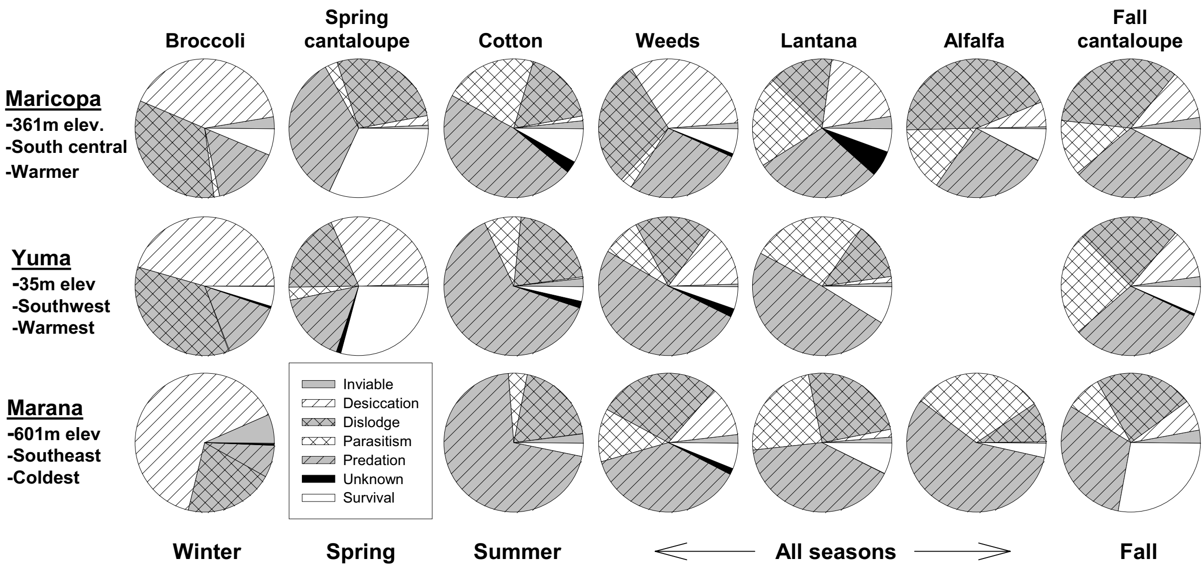

Fig. 3. Mean proportion (based on marginal mortality rates) of various mortality factors for *B. tabaci* populations on multiple host plants in three regions of Arizona, USA over a three year period. Summary based on 4-36 cohorts per host and site. Site descriptions indicate severity of winter months.

DISCUSSION.

Multiple mortality factors impact populations of *B. tabaci* and these factors along with host plant availability, dispersal and changing environmental factors govern the population dynamics of this pest insect throughout the entire year. Low populations during winter months are associated with high mortality from predation and weather related events such as dislodgement and desiccation from low temperatures along with reduced developmental and reproductive rates. Generational survivorship averaged < 9% on all host plants with the exception of spring-planted cantaloupes where survivorship averaged over 30%. Although parasitism was moderately high in these latter cases, predation was considerably lower than in others hosts and seasons. We have shown that predation is the key factor influencing variations in mortality of *B. tabaci* in the cotton system and perhaps the reduced level of this mortality factor in spring cantaloupes is associated with the lower mortality of *B. tabaci* on this crop. The high survival in the spring acts as a biological release that partial enables rapid population growth during the late spring and early summer leading to potential outbreak populations of *B. tabaci* by mid to late summer in Arizona that typically require insecticide applications for economic suppression. Better management of *B. tabaci* in spring crops such as cantaloupe may be key to population management of this pest within a region. Effort should be placed on exploring options to increase biological control during this critical portion of the season.

Predation and dislodgement from the plant surface were consistently the largest sources of mortality across all hosts and sites during most of the season with the exception of desiccation from freezing temperatures which dominated in winter grown broccoli. Compared with previous life table studies in cotton (Naranjo & Ellsworth 2005), rates of parasitism were higher in cotton and in other hosts crops in our multi-crop landscapes. Aphelinid parasitoids do not appear to be strong dispersers (Hagler *et al.* 2002; Byrne & Bellamy 2003) and the close juxtaposition of host crops in this study may have facilitated higher parasitoids populations that were able to better track host resources and thus contribute more to pest mortality. This points to the potentially important role of crop diversification and/or that active management of habitats to enhance biological control by parasitoids (Landis & Menalled 1998; Gurr *et al.* 2004). The predators in this system are mostly generalist feeders that are well adapted to disturbance and readily disperse among host plants to take advantage of the changing abundance of prey populations. Nonetheless, active habitat management could potentially enhance the efficacy and impact of generalist predators as well, especially during the spring.

We have provided only a glimpse of our overall research effort that is focused on attempting to understand the complex dynamics of *B. tabaci* within a multi-host agricultural system in Arizona. Through a landscape lens, our results provide insight for improved management of all affected crops that take advantage of natural mortality forces such as natural enemies.

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